U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

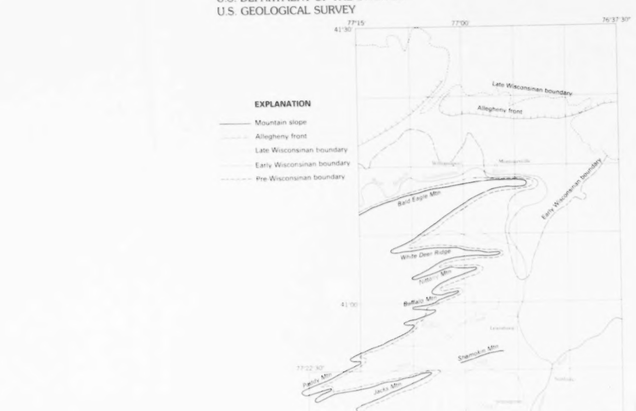
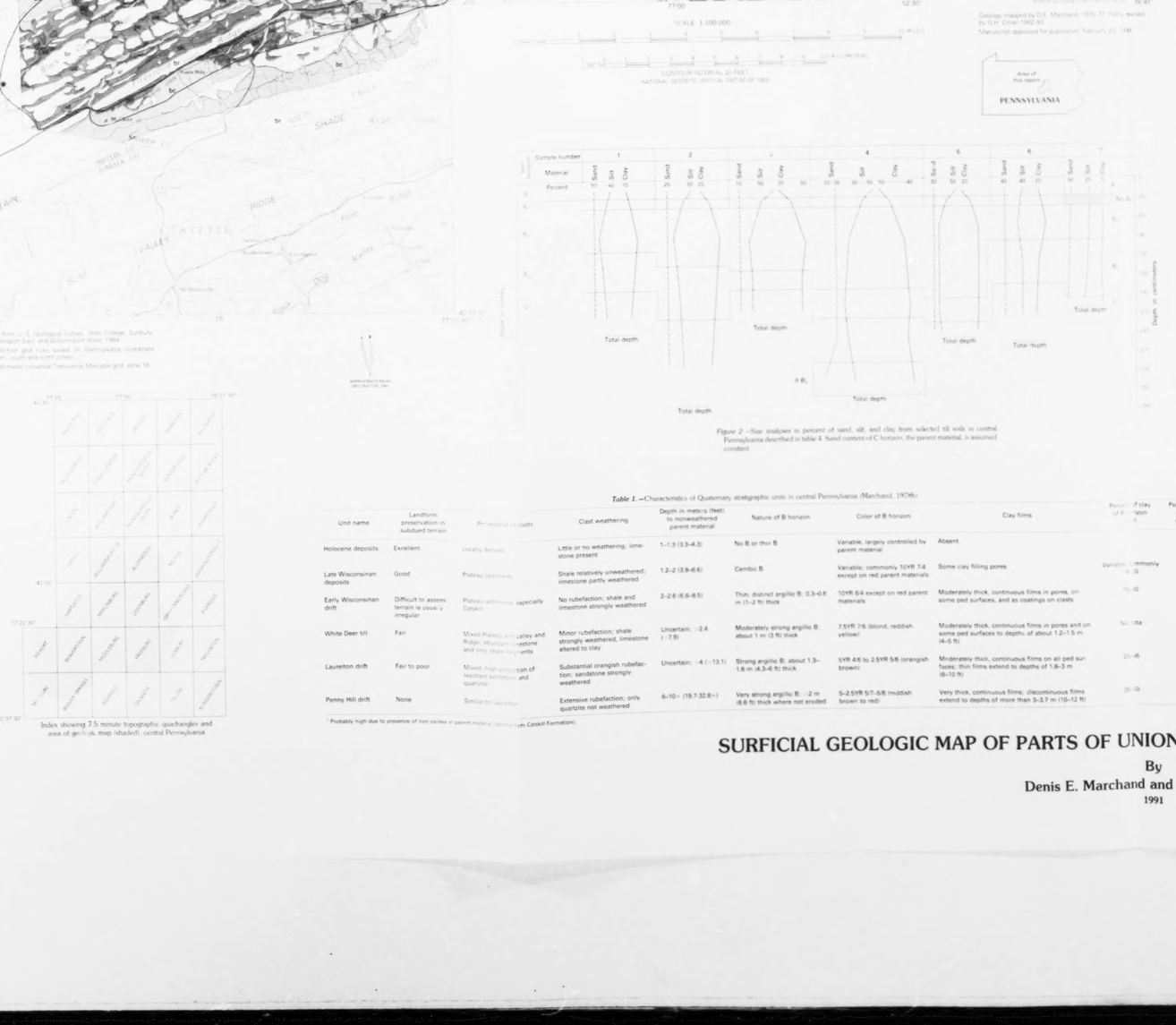


Figure 1.—Extent of glacial boundaries in central Pennsylvania.

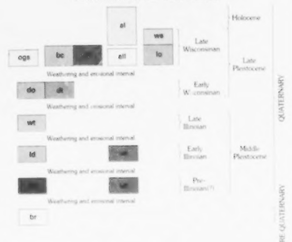

SCALE 1:100 000
CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
Geology mapped by D.E. Marchand, 1975-77. Partly revised by G.H. Crowl, 1982-83.
Manuscript approved for publication, February 23, 1990
Area of this report
PENNSYLVANIA

Base from U. S. Geological Survey, State College Sunbury, Williamsport East, and Williamsport West, 1964
25,000-foot grid ticks based on Pennsylvania coordinate system, south and north zones
10,000-meter Universal Transverse Mercator grid, zone 18

Index showing 7.5 minute topographic quadrangles and area of geologic map (shaded), central Pennsylvania

Figure 2.—Size analyses in percent of sand, silt, and clay from selected till soils in central Pennsylvania described in table 4. Sand content of C horizon, the parent material, is assumed constant.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

HOLOCENE AND LATE WISCONSINAN DEPOSITS

Holocene deposits have weakly developed soils that may lack a B horizon in some places, but which usually show incipient soil development (Blatt and Crelkose, 1977; Crelkose, 1978).

al **Alluvium**—Silt, sand, and gravel. Channel and overbank deposits in flood plain or low terrace up to 2–6 m (7–20 ft) above normal river level of the Susquehanna River and its tributaries.

LATE WISCONSINAN DEPOSITS

Soils have a cambic B horizon, which commonly is grayish orange (10YR 7/4). Depth to nonweathered parent material is 1.2–2.0 m (3.9–6.6 ft). Clay fills some pores in some colluvial soils.

ws **Windblown sand**—Chiefly fine to medium sand and silt on low terrace along the Susquehanna River.

bc **Blocky colluvium**—Subangular to angular sandstone cobbles and boulders 0.2–0.3 m (0.7–1 ft) in diameter, generally in a supporting sandy matrix; clast-supported phases are common locally. Derived from and lies on the flanks of sandstone mountain ridges. Late Wisconsinan colluvium shows argillic soil horizon development (Laidig soil series) and moderately well developed fragipan in well-drained soil (Buchanan and Andover soil series). Fresh, nonweathered parent material is normally within 1.3–1.6 m (4.3–5.2 ft) of the surface. Generally, late Wisconsinan colluvial deposits have soils with structural B, cambic horizons and moderately well to strongly developed fragipans.

bc **Colluvium**—Pebble-size subangular to subrounded fragments of sandstone, shale, or limestone in an abundant sand, silt, and clay matrix. A crudely stratified shale-chip colluvium occurs in some outcrop areas of the Trimmers Rock and Mahantango Formations. Particles of this shale-chip colluvium are 1–5 cm (0.4–2 in.) in length; the scanty matrix is weathered shale. Downslope end of colluvium interfingers with Woodfordian alluvium (map unit ath), and the surface of the colluvium is graded to the surface of outwash or alluvial terraces.

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all **Alluvium**—Silt, sand, and gravel in low terraces and alluvial fans principally along major tributaries. Extensive areas of gravelly alluvium, in low terraces and fans, are in the western part of the map area close to the mountains.

EARLY WISCONSINAN DEPOSITS

Soils have weak to moderate argillic B horizon 5–10 cm (2–4 in.) thick (Crelkose, 1978; Levine and Crelkose, 1983). Depth to fresh parent material is 2–3 m (7–10 ft). Clay content of B horizon is 15–30 percent. Color is reddish brown to weak red (5YR 5/4 to 2.5YR 4/2); it strongly reflects color of parent material. The B horizon (highly organic) displays continuous clay films in pores and over ped surfaces, and the films become discontinuous with increasing depth. Soil structure is generally fine to medium, subangular, and blocky.

do **Outwash**—Sand and gravel underlie a terrace about 25 m (82 ft) above the Susquehanna River at Shamokin Dam. Loess and silty sand cover in places. Includes dolt, chiefly sand and gravel outwash, and loess.

dt **Till**—Crops out northwest of New Columbia.

PRE-WISCONSINAN DEPOSITS

Glacial sediments strongly weathered in soil profile. B horizons are reddish yellow (7.5YR 7/6), grayish brown (5YR 4/6), or red (2.5YR 5/6) and are strongly argillic.

wt **White Deer till**—Mantled by thin loess in many places. Weathered to more than 2.5 m (8 ft); shale clasts strongly weathered, and limestone clasts altered to clay. Minor rubefaction imparts blood color. B horizon is reddish yellow (7.5YR 7/6). Afton soil on White Deer till has a moderately thick argillic B horizon having moderately thick, continuous clay films in pores, around clasts, and on some ped surfaces. Nonweathered till parent material has not been found in the map area.

ld **Laurelton drift**—Principally, till, but includes some probable stratified ice-contact deposits and local glaciofluvial, lacustrine, and eolian sediments. In some areas, till overlies glaciofluvial sand of the same age. Weathered to more than 4 m (13 ft); sandstone clasts are strongly weathered, and rubefaction is substantial. Argillic B horizons in Allenwood soil range up to 2 m (7 ft) in thickness and have moderately thick, continuous clay films around clasts and over ped surfaces. Soil structure is generally strong, medium, angular, and blocky. Many shale and sandstone fragments in the soil show rubefaction and thick weathering rinds. B horizon appears grayish brown (5YR) rather than reddish yellow (7.5YR) in road cuts and in plowed fields.

wt **Penny Hill drift**—Principally, till, but includes some probable stratified ice-contact deposits and other minor glaciofluvial, colluvial, and eolian materials. Weathered to a depth of more than 6 m (20 ft); sandstone clasts are strongly weathered, and rubefaction is extensive. Allenwood soils on Penny Hill drift are generally redder and brighter than soils on the Laurelton drift and White Deer till (yellowish red to red; 5YR 4/6 to 2.5YR 5/6). In the argillic B horizon very thick continuous clay films around clasts and over ped surfaces extend to depths of more than 3 m (10 ft). In relatively unmodified soil profiles. Soil structure is commonly coarse, angular, and blocky.

ud **Pre-Wisconsinan deposits, undifferentiated**—Till, colluvium, lacustrine, and fluvial deposits overlain by thin colluvium or alluvium in many places.

br **Bedrock**—Sandstone, shale, limestone, or chert, may include thin colluvium on slopes and in swales. Locally includes thin deposits (less than 0.6 m (2 ft)) of till.

EXPLANATION OF MAP SYMBOLS

Contact
Pre-Wisconsinan drift boundary
Quarry
● **Erratic boulder at ice limit in Mc Clure quadrangle**
x **Location of measured section (see table 2)**

DISCUSSION

EXPLANATORY NOTE

Both authors are deceased (1981 and 1967, respectively). Denis Marchand, U.S. Geological Survey, mapped the area of this report at the scale of 1:24,000 (Marchand, 1978a). These maps were reduced and generalized to the present scale of 1:100,000 and the present report was prepared by George Crowl, Ohio Wesleyan University. Byron D. St.ne, U.S. Geological Survey, reviewed this report and accepted the authors' responsibilities of review and revision.

INTRODUCTION

This map shows the distribution of pre-Wisconsinan drift and younger glacial and nonglacial sediments of central Pennsylvania west of the Susquehanna River. The map also shows the generalized border of these glacial deposits, which may be related to one or more middle Pleistocene glaciations. Remnants of the older glacial deposits in the map area are thin, scattered, and poorly exposed. In many places only scattered erratics indicate the inferred extent of any glaciation. Because of the sparse distribution of drift and the similarity of some of the residual deposits and older drifts, previous workers, for example, Leverett, 1934) have questioned the extent of glaciation in the valleys west of the Susquehanna River.

In this study, geologic interpretation of soil-series map units was used to help map the distribution of surficial geologic materials. This method allowed a more detailed map coverage than reliance on widely scattered outcrops of those materials. Detailed preliminary geologic maps (Marchand, 1978a, scale 1:24,000) that were derived from soil survey maps of the two counties (Bacon and others, 1946; Parrish and Derr, 1971) were modified after examining the surficial deposits in the field. The distribution of most surficial deposits shown on the present map is related directly to the mapped soils series. Land is modified on the basis of additional field observations by Marchand. Field checking during the spring and fall plowing seasons was particularly helpful, because distinctive materials and colors of the shallow bedrock and most surficial materials were most pronounced. The surficial deposits were differentiated and assigned relative ages on the basis of geographic distribution, superposition, and degree of weathering, soil development, erosional dissection, and preservation.

Map units shown here are generalized because of limitations of map scale, because soil units sometimes included more than one geologic parent material, and because some soil units were redefined in order to correlate better with geologic materials. For example, stony colluvium of Wisconsinan age derived from high quartzite ridges is mapped chiefly as the Laidig, Buchanan, and Andover soil series. The Lesterfort and Penny Hill drifts were correlated with Allenwood, Alvira, Watson, and Shelmadine soils. The undifferentiated deposits of pre-Wisconsinan age, related to some Watsoa, Alvira, and Shelmadine soils, include till, alluvium, colluvium, pond deposits, and local areas of soil residual with formed on bedrock. Bedrock axes, in the lowlands locally have a thin, discontinuous layer of till, colluvium, or residual soil developed subsequent to the last pre-Wisconsinan glaciation in the area. Generally, surface materials less than 0.6 m (2 ft) thick are mapped as the underlying material. In some places, till underlying colluvium was noted but not mapped.

REGIONAL SETTING

Union and Snyder Counties are east of the Susquehanna River in the Valley and Ridge province of the Appalachian Highlands in central Pennsylvania (fig. 1). Major anticlines and synclines plunge east-northeast. Jacks Mountain and its eastward extension, Shamokin Mountain, divide the map area into northern highlands and southern lowlands characterized by strike ridges and valleys. The lowlands are separated to the west and open eastward. The Silurian Tuscarora Sandstone forms the high mountain ridges in the west and northwest parts of the area. The Silurian Bloomsburg Red Beds and Devonian Catskill Formation, both composed of interbedded shale and carbonate rocks, are the principal rock units in the lowland sections, and they have provided most of the red clasts in the glacial sediments.

Pre-Wisconsinan glacial ice from the north and northeast entered the lowlands and extended up the valleys to buttress against the mountain ridges. The ice reached farther south in the Susquehanna valley. The pre-Wisconsinan drift in the area have been assigned an Illinoian age (Berg and others, 1980, 1985), but they are far from certain of Illinoian age. The age assignment was based on the work of Leverett (1934) and on correlation with deposits in northeastern Pennsylvania (Sharpe and others, 1939; White and others, 1969; White, 1982). Leverett (1934) concluded that Illinoian ice advanced down the valley of the West Branch Susquehanna River to the vicinity of Allenwood and down the valley of the Susquehanna River to Enrolling. He interpreted drift deposits between these valleys as pre-Illinoian in age, and west of the Susquehanna River, he termed the drifts pre-Illinoian and of "questionable Kansan" age. These conclusions were understandable in light of widely scattered outcrops and poor exposures of drift, but such conclusions are not tenable in light of modern information.

Early Wisconsinan drift is close to the Susquehanna River in the northeast corner of the map area (Hall and others, 1977), and late Wisconsinan drift is on the Appalachian Plateau about 32 km (20 mi) north (Crowl and Sevon, 1980). Late Wisconsinan outwash is confined to the vicinity of the Susquehanna River and underlies much of the main alluvium.

THE PRE-WISCONSINAN DRIFT BOUNDARY

The generalized boundary of pre-Wisconsinan drift here (fig. 1) is a revision of that shown on the geologic map of Pennsylvania (Berg and others, 1980). The boundary is not on the drift map and is based on unpublished data of Marchand. South of here (west of Mifflinburg and McClure) on the Juniata River are exposures having Allenwood soil profiles that have been interpreted as Illinoian drift by many geologists. On the basis of these exposures, Marchand extended the Illinoian glacial boundary southward to bring narrow tongues of drift on either side of Shade Mountain. However, the mapped extent of these narrow tongues of drift cannot represent the realistic configuration of glacial lobes in the valleys. Furthermore, Allenwood series and closely related soil profiles have developed in some residual soils on the nonglaciated plateau and in some old alluvium along the Allegheny Front southwest of the Juniata River (Ed. Colborne and others, personal commun., 1984). During reconnaissance mapping in 1982–83, Crowl found no drift in Allenwood series soils in the valleys between this map area and the Juniata River deposits. A distance of nearly 40 km (25 mi). The discontinuous farming Allenwood soils near Mifflinburg and McClure are now interpreted as old alluvial terrace deposits.

The mapped boundary of Illinoian drift south of the map area is marked by a short tongue in the Susquehanna valley as far south as Mahantango Creek (fig. 1) (Hoskins and Sevon, 1976). Thence, it extends irregularly west across southern Snyder County as Harris earth on the west side of the North Branch of Mahantango Creek to the vicinity of Mount Pleasant Mills, where it turns northward and wraps around the end of Shade Mountain. Recently discovered scattered remnants of Illinoian drift and stony Allenwood soil profiles north and east of the inferred boundary and the complete absence of drift west of the boundary support the currently mapped position of the pre-Wisconsinan border. The drift border in the southwest corner of the geologic map is based on the presence of the last erratic boulder. To the southwest, all surficial materials are residual, soils, colluvium, and alluvium.

The drift boundary shown on the geologic map approximately is close to the border of glaciation. The gradient of the boundary, which reflects the gradient of the ice surface is low, but notable. There are two controls on the gradient—the altitude of the border on Bald Eagle Mountain and the altitude of the Susquehanna River at M.Kees Hall Falls (fig. 1). No drift has been found south of Bald Eagle Mountain. Therefore, that mountain was not covered by ice, and a probable altitude of the glacial border is about 440 m (1,450 ft). The altitude of the border at M.Kees Hall Falls is 128 m (420 ft). These figures determine an ice surface gradient of 8 meters (26 ft/mi).

SURFICIAL DEPOSITS

Surficial materials in the region include residual soils, colluvium, alluvium, and discontinuous deposits of glacial drift. Most previous studies (Leverett, 1934; Denny and Lyford, 1963; Braun, 1976; Marchand, 1978a, b; Crowl and Sevon, 1980) have concentrated on areas north of here.

Residual soils and colluvium are derived from underlying and subjacent bedrock lithologies, and the rock fragments in these materials are angular. Most colluvium has a downslope fabric of chimney sandstone fragments. Marchand (1978a, b) distinguished three pre-Wisconsinan drifts, principally on the basis of color, and he assigned them different ages.

Pre-Wisconsinan deposits

Only one pre-Wisconsinan drift (—Illinoy drift has been recognized by Wells and Berg (1980) and Crowl and Sevon (1980) of the Pennsylvania Geological Survey. Marchand (1978a, b), on the other hand, distinguished three deeply weathered, red-brown pre-Wisconsinan drifts in this area largely by subtle color and weathering differences, and he assigned different ages to them on the basis of geographic distribution—the drift farthest south and west is the oldest, and the drift becomes younger in sequence to the north. These are informally named the Penny Hill drift, the Laurelton drift, and the White Deer till, in order of decreasing age (Marchand, 1978b). Composition of the three drifts varies slightly with locality, but the tills characteristically contain erratic clasts derived from the Tuscarora Sandstone. Locally as much as 10 percent Any carbonate rock fragments originally present have weathered to clay. There are no crystalline erratics. The abundance of local rocks and similar erratic lithologies in all the tills indicate a similar northerly provenience for all the drifts. The three drifts are difficult to distinguish from one another by color on the basis of field criteria only, and locally they may be only different varieties of the same till. Buried soil profiles, marking divisions between drifts are visible only in fresh excavations. All pre-Wisconsinan drifts carry an Allenwood series or closely related soil profile. Characteristics of the three drifts and younger deposits are summarized in table 1.

Penny Hill drift

The type area of Penny Hill drift is at Penny Hill on U.S. Route 15 north of Allenwood (Denny and Lyford, 1963; detailed description of a truncated soil profile). The Penny Hill drift is similar to the Muncy drift of the Pennsylvania Geological Survey (Wells and Berg, 1980; Crowl and Sevon, 1980). This drift includes till and minor stratified ice-contact and glaciofluvial deposits that crop out in the southeastern part of the map area in areas overlying deposits may have been stripped away. Most outcrops are small, widely separated, and expose less than 2 m (6 ft) of drift.

Till of the Penny Hill drift is common beneath Wisconsinan or older colluvium on low ridge slopes. At a quarry between Beaverdam and Mifflinburg, well-weathered till underlies a colluvium having a soil mat is similar to a ped Laurelton soil. West of Selinsgrove in a basement excavation, probable Penny Hill till underlies till of the Laurelton drift. In two large areas mapped as unit ud, on the south slopes of Nittany and Buffalo Mountains, the till displays characteristics that are intermediate between Penny Hill and Laurelton tills, probably a result of variation in composition. However, after further examination of other temporary exposures Crowl concluded these tills probably belong to the Penny Hill drift.

Table 1.—Characteristics of Quaternary stratigraphic units in central Pennsylvania (Marchand, 1978b)

Unit name	Landform preservation in subdued terrain	Provenance of clasts	Clast weathering	Depth in meters (feet) to nonweathered parent material	Nature of B horizon	Color of B horizon	Clay films	Percent of clay of B horizon	Percent of free iron oxides in B and upper C till soils
Holocene deposits	Excellent	Locally derived	Little or no weathering; limestone present	1–1.3 (3.3–4.3)	No B or thin B	Variable, largely controlled by parent material	Absent		
Late Wisconsinan deposits	Good	Plateau sediments	Shale relatively unweathered; limestone partly weathered	1.2–2 (3.9–6.6)	Cambic B	Variable, commonly 10YR 7/4 except on red parent materials	Some clay filling pores	Variable, commonly 9–10	0.5–1.2
Early Wisconsinan drift	Difficult to assess; terrain is usually irregular	Plateau sediments, especially Catskill	No rubefaction; shale and limestone strongly weathered	2–2.6 (6.6–8.5)	Thin, distinct argillic B; 0.3–0.6 m (1–2 ft) thick	10YR 6/4 except on red parent materials	Moderately thick, continuous films in pores, on some ped surfaces, and as coatings on clasts	15–30	2.9–5.0
White Deer till	Fair	Mixed; Plateau and valley and Ridge; abundant limestone and limy shale fragments	Minor rubefaction; shale strongly weathered, limestone altered to clay	Uncertain; ~2.4 (~7.9)	Moderately strong argillic B; about 1 m (3 ft) thick	7.5YR 7/6 (blond, reddish yellow)	Moderately thick, continuous films in pores and on some ped surfaces to depths of about 1.2–1.5 m (4–5 ft)	No data	No data
Laurelton drift	Fair to poor	Mixed; high proportion of resistant sandstone and quartzite	Substantial orangish rubefaction; sandstone strongly weathered	Uncertain; ~4 (~13.1)	Strong argillic B; about 1.3–1.8 m (4.3–6 ft) thick	5YR 4/6 to 2.5YR 5/6 (orangish brown)	Moderately thick, continuous films on all ped surfaces; thin films extend to depths of 1.8–3 m (6–10 ft)	20–46	2.5–6.3
Penny Hill drift	None	Similar to Laurelton	Extensive rubefaction; only quartzite not weathered	6–10+ (19.7-32.8+)	Very strong argillic B; ~2 m (6.6 ft) thick where not eroded	5–2.5YR 5/7–5/8 (reddish brown to red)	Very thick, continuous films; discontinuous films extend to depths of more than 3–3.7 m (10–12 ft)	35–50	4.8–6.8

[1] Probably high due to presence of iron oxides in parent material (sandstone from Catskill Formation).

Table 4.—Samples from selected till soils in central Pennsylvania analyzed in figure 2

Sample	Soil	Location	Till	Reference
1	Allenwood silt loam	Hughesville, Lycoming County	Penny Hill (Muncy)	Denny and Lyford, 1963, p. 31
2	Allenwood silt loam	Allenwood Prison Camp, Union County	White Deer	Marchand and others, 1978, p. 41–42, 56, and 86.
3	Allenwood silt loam	Snyder County	Pre-Wisconsinan	Marchand and others, 1978, p. 56–62, 67, and 84
4	Allenwood loam	Hartleton, Union County	Laurelton	Marchand and others, p. 60–68, 70, and 88.
5	Allenwood silt loam	Penns Creek, Snyder County	Laurelton	Marchand and others, 1978, p. 59–67, and 82
6	Leck Kill channery silt loam	Fairfield township, Lycoming County	Altonian (Warrensville?)	Marchand and others, 1978, p. 65, and 80.
7	Lackawanna channery loam	Monroe County	Olean	Marchand and others, 1978, p. 63 and 76.

SURFICIAL GEOLOGIC MAP OF PARTS OF UNION AND SNYDER COUNTIES, PENNSYLVANIA

By
Denis E. Marchand and George H. Crowl

1991

Geology mapped by D.E. Marchand, 1975–77. Partly revised by G.H. Crowl, 1982–83.
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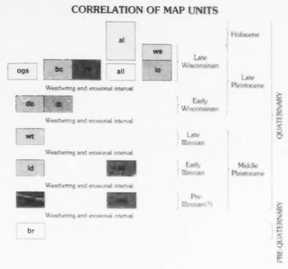

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Glacial sediments strongly weathered in soil profile. B horizons are reddish yellow (7.5YR 7/6), grayish brown (5YR 4/6), or red (2.5YR 5/6) and are strongly argillic

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DISCUSSION

EXPLANATORY NOTE

Both authors are deceased (1981 and 1987, respectively). Denis Marchand, U.S. Geological Survey, mapped the area of this report at the scale of 1:24,000 (Marchand, 1978a). These maps were reduced and generalized to the present scale of 1:100,000 and the present report was prepared by George Crowl, Ohio Wesleyan University, Byron D. Stone, U.S. Geological Survey, reviewed this report and accepted the authors' responsibilities of review and revision.

INTRODUCTION

This map shows the distribution of pre-Wisconsinan drift and younger glacial and nonglacial sediments of central Pennsylvania west of the Susquehanna River. The map also shows the generalized border of these glacial deposits, which may be related to one or more middle Pleistocene glaciations. Remnants of the older glacial deposits in the map area are thin, scattered, and poorly exposed. In many places only scattered erratics indicate the inferred extent of any glaciation. Because of the sparse distribution of drift and the similarity of some of the residual deposits and older drifts, previous workers (for example, Leverett, 1934) have questioned the extent of glaciation in the valleys west of the Susquehanna River.

In this study, geologic interpretation of soil-series map units was used to help map the distribution of surficial geologic materials. This method allowed a more detailed map coverage than reliance on widely scattered outcrops of these materials. Detailed preliminary geologic maps (Marchand, 1978a, scale 1:24,000) that were derived from soil-survey maps of the two counties (Bacon and others, 1946; Parrish and Derr, 1971), were modified after examining the surficial deposits in the field. The distribution of most surficial deposits shown on the present map is related directly to the mapped soils series, but is modified on the basis of additional field observations by Marchand. Field checking during the spring and fall plowing seasons was particularly helpful, because distinctive materials and colors of the shallow bedrock and moist surficial materials were most pronounced. The surficial deposits were differentiated and assigned relative ages on the basis of geographic distribution, superposition, and degree of weathering, soil development, erosional dissection, and preservation.

Map units shown here are generalized because of limitations of map scale, because soil units sometimes included more than one geologic parent material, and because some soil units were redefined in order to conform better with geologic materials. For example, stony colluvium of Wisconsinan age derived from high quartzite ridges is keyed chiefly to the Laidig, Buchanan, and Andover soil series. The Laurelton and Penny Hill drifts were correlated with Allenwood, Alvira, Watson, and Shelmadine soils. The undifferentiated deposits of pre-Wisconsinan age, related to some Watson, Alvira, and Shelmadine soils, include till, alluvium, colluvium, pond deposits, and local areas of red residual soils formed on bedrock. Bedrock areas in the lowlands locally have a thin, discontinuous (less than 0.6 m (2 ft)) veneer of colluvium, or residual soil developed subsequent to the last pre-Wisconsinan glaciation in the area. Generally, surface materials less than 0.6 m (2 ft) thick are mapped as the underlying material. In some places, till underlying colluvium was noted but not mapped.

REGIONAL SETTING

Union and Snyder Counties are west of the Susquehanna River in the Valley and Ridge province of the Appalachian Highlands in central Pennsylvania (fig. 1). Major anticlines and synclines plunge east-northeast. Jacks Mountain and its eastward extension, Shamokin Mountain, divide the map area into northern highlands and southern lowlands characterized by strike ridges and valleys. The lowlands are constricted to the west and open eastward. The Silurian Tuscarora Sandstone forms the high mountain ridges in the west and northwest parts of the area. The Silurian Bloomsburg Red Beds and Devonian Catskill Formation, both composed of nonresistant shale and carbonate rocks, are the principal rock units in the lowland sections, and they have provided most of the red clasts of the glacial sediments.

Pre-Wisconsinan glacial ice from the north and northeast covered the lowlands and extended up the valleys to buttress against the mountain ridges. The ice reached farthest south in the Susquehanna valley. The pre-Wisconsinan drifts in the area have been assigned an Illinoian age (Berg and others, 1980, 1983), but they are far from outcrops of known Illinoian drift. The age assignment was based on the work of Leverett (1934) and on correlation with deposits in northwestern Pennsylvania (Sheppis and others, 1959; White and others, 1969; White, 1982). Leverett (1934) concluded that Illinoian ice advanced down the valley of the West Branch Susquehanna River to the vicinity of Allenwood and down the valley of the Susquehanna River to Freeburg. He interpreted drift deposits between these valleys as pre-Illinoian in age, and west of the Susquehanna River, he termed the drifts pre-Illinoian and of "questionable location" (age). These conclusions were understandable in light of widely scattered outcrops and poor exposures of drift, but such conclusions are not tenable in light of modern information.

Early Wisconsinan drift is close to the Susquehanna River in the northeast corner of the map area (Fail and others, 1977), and late Wisconsinan drift is on the Appalachian Plateau about 32 km (20 mi) north (Crowl and Sevon, 1980). Late Wisconsinan outwash is confined to the vicinity of the Susquehanna River and underlies much of the river alluvium.

THE PRE-WISCONSINAN DRIFT BOUNDARY

The generalized boundary of pre-Wisconsinan drift here (fig. 1) is a revision of that shown on the geologic map of Pennsylvania (Berg and others, 1980). The boundary shown on the state map was based on unpublished data of Marchand. South of here near Mifflinburg and McClure on the Juniata River are diamictons having Allenwood series soil profiles that have been interpreted as Illinoian drift by many geologists. On the basis of these exposures, Marchand extended the drift border southward, southwest in two long narrow tongues of drift on either side of Shade Mountain. However, the mapped extent of these narrow tongues of drift cannot represent the realistic configuration of glacial lobes in the valleys. Furthermore, Allenwood series and closely related soil profiles have developed in some residual soils on the nonglaciated plateau and in some old alluvium along the Allegheny Front southwest of the Juniata River (E.J. Ciolkosz and others, personal commun., 1984). During reconnaissance mapping in 1982–83, Crowl found no drift of Allenwood series soils in the valleys between this map area and the Juniata River deposits, a distance of nearly 40 km (25 mi). The diamictons having Allenwood soils near Mifflinburg and McClure are now interpreted as old alluvial terrace deposits.

The revised boundary of Illinoian drift south of the map area is marked by a short tongue in the Susquehanna valley as far south as Mahantango Creek (fig. 1). Hoskins and Sevon, 1976). There, it extends irregularly west across southern Snyder County, and turns north on the west side of the North Branch of Mahantango Creek to the vicinity of Mount Pleasant Mills, where it turns northeast and wraps around the end of Shade Mountain. Recently discovered scattered remnants of Illinoian drift and stony Allenwood soil profiles north and east of the inferred boundary and the complete absence of drift west of the boundary support the currently mapped position of the pre-Wisconsinan border. The drift border in the southwest corner of the geologic map is based on the presence of the last erratic boulder. To the southwest, all surficial materials are residual soils, colluvium, and alluvium.

The drift boundary shown on the geologic map presumably is close to the border of glaciation. The gradient of the boundary, which reflects the gradient of the ice surface, is low, but realistic. There are two controls on the gradient—the altitude of the border on Bald Eagle Mountain and the altitude of the Susquehanna River at McKees Half Falls (fig. 1). No drift has been found south of Bald Eagle Mountain. Therefore, that mountain was not covered by ice, and a probable altitude of the glacial border is about 440 m (1450 ft). The altitude of the border at McKees Half Falls is 128 m (420 ft). These figures determine an ice-surface gradient of 5 m/km (26 ft/mi).

SURFICIAL DEPOSITS

Surficial materials in the region include residual soils, colluvium, alluvium, and discontinuous deposits of glacial drift. Most previous studies (Leverett, 1934; Denny and Lyford, 1963; Bucek, 1976; Marchand, 1978a, b; Crowl and Sevon, 1980) have concentrated on areas north of here.

Residual soils and colluvium are derived from underlying and upslope bedrock lithologies, and the rock fragments in these materials are angular. Most colluvium has a downslope fabric of channeled, subangular fragments. Marchand (1978a, b) distinguished three pre-Wisconsinan drifts principally on the basis of color, and he assigned them different ages.

Pre-Wisconsinan deposits

Only one pre-Wisconsinan drift, the Muncy drift, has been recognized by Wells and Bucek (1980) and Crowl and Sevon (1980) of the Pennsylvania Geological Survey. Marchand (1978a, b), on the other hand, distinguished three deeply weathered red-brown pre-Wisconsinan drifts in this area largely by subtle color and weathering differences, and he assigned different ages to them on the basis of geographic distribution—the drift farthest south and west is the oldest, and the drift becomes younger, in sequence, to the north. These are informally named the Penny Hill drift, the Laurelton drift, and the White Deer till, in order of decreasing age (Marchand, 1978b). Composition of the three drifts varies slightly with locality, but the tills characteristically contain erratic clasts derived from the Tuscarora Sandstone, locally as much as 10 percent. Any carbonate-rock fragments originally present have weathered to clay. There are no crystalline erratics. The abundance of local rocks and similar erratic lithologies in all the tills indicate a similar northerly provenance for all the drifts. The three drifts are difficult to distinguish from one another by color on the basis of field criteria only, and locally they may be only different varieties of the same till. Buried soil profiles, marking intervals between drifts, are visible only in fresh excavations. All pre-Wisconsinan drifts carry an Allenwood series or closely related soil profile. Characteristics of the three drifts and younger deposits are summarized in table 1.

Penny Hill drift

The type area of Penny Hill drift is at Penny Hill on U.S. Route 15 north of Allenwood (Denny and Lyford, 1963, detailed description of a truncated soil profile). The Penny Hill drift is similar to the Muncy drift of the Pennsylvania Geological Survey (Wells and Bucek, 1980; Crowl and Sevon, 1980). This drift includes till and minor stratified ice-contact and glaciofluvial deposits that crop out in the southwestern part of the map area or where overlying deposits may have been stripped away. Most outcrops are small, widely separated, and expose less than 2 m (6 ft) of drift.

Till of the Penny Hill drift is common beneath Wisconsinan or older colluvium on low ridge slopes. At a quarry, between Beaverstown and Middleburg, well-weathered till underlies a colluvium having a soil that is similar to a post-Laurelton soil. West of Selinsgrove in a basement excavation, probable Penny Hill till underlies till of the Laurelton(?) drift. In two large areas mapped as unit ud, on the south slopes of Nittany and Buffalo Mountains, the till displays characteristics that are intermediate between Penny Hill and Laurelton tills, probably a result of variation in composition. However, after further examination of other temporary exposures, Crowl concluded these till probably belong to the Penny Hill drift.

Gray, nonweathered Penny Hill till was exposed temporarily at a depth of 7–10 m (23–33 ft) in a road cut during the construction of U.S. Route 220 east of Montoursville (fig. 1; Bucek, 1976). This is the only known exposure of nonweathered Penny Hill drift in the region.

Laurelton drift

Laurelton drift includes principally till and lesser amounts of stratified ice-contact and glaciofluvial deposits. It is named for Laurelton in the Hartleton quadrangle.

The Laurelton drift has widespread, patchy, generally thin distribution in the lowlands. It extends over the Buffalo Creek, Penns Creek, and Middle Creek valleys. Only two areas of thick drift are known, one (5 m (16 ft) thick) at a borrow pit in glaciofluvial materials on U.S. Interstate 80 near the New Columbia Interchange (Allenwood Milton quadrangles) and the other in till of an end moraine near Laurelton.

The Laurelton end moraine is a broad, irregular, cross-valley ridge, about 15 m (50 ft) high and 2 km (1.2 mi) long, which almost blocks the valley of Penns Creek at Glen Iron. Its southern part near the creek is indistinct, its central part is distinct, and its northern part grades into a long slope of Wisconsinan boulder colluvium about 1 km (0.6 mi) west of Laurelton. Presumably, slope movement from Paddy Mountain reworked the till of the moraine.

Two other areas of possible end moraine are 1.5 km (0.9 mi) east of the village of Penns Creek (Middleburg quadrangle) and on the mountain slope east of Troxelville (Beavertown quadrangle). Both are areas of low knob and swale topography, and the swales have an organic-rich soil. Trimmers Rock Formation, mainly sandstone, underlies the irregular topography near Penns Creek, and the sandstone may well have influenced the topographic high of this end moraine. By contrast, the swale topography east of Troxelville overlies carbonate-rich rock of the Ks, Keyser Formation and adjacent formations (Berg and Dodge, 1981), and the swales probably resulted from collapse of surface materials into underlying sink holes. They are analogous to sink holes on the McElhattan alluvial fan in the Jersey Shore quadrangle (Crowl, unpublished data, 1983).

In a pit in the end moraine west of Laurelton, Laurelton till overlies a soil horizon in which weathered shale fragments make up about 75 percent of the material in a clay matrix. This IIB_t horizon is interpreted as a residual soil (E.J. Ciolkosz, personal commun., 1983).

White Deer till

White Deer till is named for exposures in White Deer valley just north of the map area. The till is well preserved in White Deer valley, and remnants extend down the West Branch Susquehanna River valley as far south as New Columbia and slightly south of the early Wisconsinan border. Another area of the till lies west and north of Selinsgrove about 32 km (20 mi) to the south. The White Deer till tends to be more continuous in coverage within its local area than the Laurelton drift.

In several soil characterization pits in White Deer valley, the White Deer till clearly is superposed on till of the Laurelton drift; in other pits, superposition is questionable. The two drifts are separated locally by a well-developed buried soil, which indicates a long period of weathering of the Laurelton drift.

Undifferentiated Pre-Wisconsinan deposits

Undifferentiated pre-Wisconsinan deposits throughout the area include colluvium, fluvial and lacustrine deposits, and some inferred till. They are widespread and overlain in many places by thin younger colluvium or alluvium. Their diagnostic features are too indistinct to allow further differentiation at the scale of this map.

Wisconsinan deposits

Early Wisconsinan drift

The early Wisconsinan drift boundary extends irregularly south of the late Wisconsinan boundary, throughout much of central Pennsylvania and down the West Branch Susquehanna River as far south as New Columbia (fig. 1). This drift is correlated with the Wyoming valley drift, described as Altonian (early Wisconsinan) in age (Wells and Bucek, 1980; Crowl and Sevon, 1980; Berg and others, 1980).

Early Wisconsinan drift includes till and stratified ice-contact deposits and outwash. Drift, colluvium, and loess deposits are exposed in a few localities in the northeast corner of the map. Outwash in the West Branch Susquehanna River valley and loess on the hills are highly eroded and are patchy in distribution. Most colluvium apparently was eroded or reworked during late Wisconsinan time.

Late Wisconsinan deposits

Late Wisconsinan age deposits include outwash terrace gravel, eolian sand, loess, and alluvium in the stream and river valleys. Colluvium mantles the mountain slopes.

Although a number of outwash terraces have been recognized in various parts of the Susquehanna River valley (Peltier, 1949; Marchand, 1973; Bucek, 1976), only one terrace 10–12 m (33–39 ft) above river level has been mapped in this area.

Eolian sand forms low dunes on the flood plain east of the Susquehanna River, including West Branch (Chase, 1977). Loess intermittently caps terrace remnants and low bedrock hills along the river. Much of the loess probably accumulated in late Wisconsinan time following ice retreat when vegetation was at a minimum.

Colluvium mantles the lower portions of most slopes in the area. Material of map unit lc, on higher mountain slopes, is coarse, blocky, and has a small amount of fine-grained matrix. This blocky colluvium is essentially clast supported, and it might well be described as scree. Map unit ge, on lower hillsides, is pebbly and has an abundant fine-grained matrix so that the clasts are matrix supported. The history of both colluviums is complex. For many, mixed, text in pre-Wisconsinan time and again during the Wisconsinan glaciations. Today, colluvium covered by vegetation is not moving extensively, and, in some cases, soil profiles on stationary colluvium have been truncated by recent erosion.

The extensive mantle of boulder colluvium on the mountain slopes is interrupted by broad, nearly colluvial fans along many of the mountain streams, but the fans have not been mapped separately. The fans are readily apparent on the 1:24,000-scale topographic maps where the contours bulge downstream. Excellent examples of fans in the Beavertown quadrangle are along the runs on the south slope of Jacks Mountain and also southward of Glen Iron on the north slope of Jacks Mountain. The latter is readily apparent when viewed from a distance. The material in both the colluvial aprons and the fans is mostly debris of boulders, are angular to subangular, and fine material increases downslope. These materials and textural changes are well exposed in temporary excavations along new Route 235 from Troxelville north to the gap.

Fans on the south slope of Jacks Mountain show a marked "stair-step" topography, having treads about 0.4 km (0.2 mi) wide and risers 3–6 m (10–20 ft) high. This topography and the coarse angular materials in the wedges are interpreted as a succession of debris flows that extended successively shorter distances downslope from the head of the continual alluvial fans, composed of principally water-transported debris, have gentle surface slopes.

An instructive section exposing multiple colluviums is in a roadcut on the north side of Penns Creek 3 km (1.9 mi) west of state Route 104 northwest of the village of Penns Creek at an altitude of 170.7 m (560 ft) (table 2). From this section we have deduced that gravel mechanics deposited Laurelton sands and silts, and subsequent downslope gravel mechanics deposited plain, colluvium. An Allenwood soil profile developed on this colluvium during the Sangamonian interglacial stage. The indistinct stone line within the Allenwood soil may indicate a subsidiary movement and subsequent stabilization. During Wisconsinan glaciation, the slope was again mobilized and gray colluvium accumulated. Locally, only channery colluvium accumulated, possibly as a result of clearing and cultivation.

Table 2.—Measured section of multiple colluviums from road cut 3 km (1.9 mi) west of state Route 104, Mifflinburg quadrangle

Thickness (m (ft))	Unit	Description
0–1.0 (0–3)	Holocene colluvium	Channery sandstone fragments supported in a silty yellow-gray matrix. On an apparently once cultivated moderately steep slope that is now overgrown with grass and young trees.
1.0–2.5 (3–8)	Wisconsinan colluvium	Gray, platy shale particles derived from local bedrock upslope. Nonweathered material; presumably weathered material stripped before deposition of overlying colluvium.
2.5–3.5 (8–11)	Pre-Wisconsinan colluvium (post-Laurelton drift)	Platy brown-red (5YR 4/6) shale particles that have an Allenwood soil profile. An indistinct stone line is midway within the colluvium.
3.5–4.0 (11–13)	Pre-Wisconsinan colluvium (Laurelton drift)	Mottled gray and yellow sand, silt, and some pebbles. Probably kame sand and silt.
	Silurian Clinton Formation	Gray shale

Holocene deposits

Holocene alluvium includes channel and overbank deposits in the flood plain of the Susquehanna River and its tributaries. The high flood plain, or low terrace, that now is mostly flooded is underlain by silt and sand that overlie coarse gravel at a depth of about 3 m (10 ft). The coarse gravel extends upstream to the late Wisconsinan drift border as the Holocene outwash deposits of late Wisconsinan age. In some places, the gravel has been truncated prior to deposition of the silt.

Alluvial deposits on the floors of the tributary valleys can only be assigned a Holocene to late Wisconsinan age. Holocene depositional and erosional surfaces have developed soils that, in some places, lack a B horizon, but commonly show incipient soil development (Bilz and Ciolkosz, 1977; Ciolkosz, 1978). Local erosion and dissection of late Wisconsinan colluvium on steep slopes demonstrate Holocene erosion. Areas of Holocene colluvium are generally too small to map, even at a scale of 1:24,000.

WEATHERING OF THE DRIFTS

Soils in the pre-Wisconsinan drifts are characterized by deep weathering (10 m (33 ft) or more in thick drift), strong brown red oxidation (5YR 5/8), and abundant pedogenic clay. The soils apparently become redder with increasing age (table 3). In contrast, soils on late Wisconsinan drifts are weakly developed, and the C horizon is approximately the color of the underlying bedrock and shows the development of only a slight textural B horizon. Soils on early Wisconsinan drift have a lower chroma than soils on late Wisconsinan drift, and the B horizon of the earlier drift has a better developed texture. The soils developed in late Wisconsinan drifts indicate that the postglacial weathering interval in late Wisconsinan and Holocene time has been shorter than the pre-Wisconsinan weathering interval and, possibly, that the weathering process was less intense during the relatively cooler climate.

Particle-size distributions in selected soil profiles are shown in figure 2. Usually, particle-size analyses of soils are given in measured percentages of sand, silt, and clay, but these analyses have been recalculated using the sand content of the C horizon as a constant in order to show the relative increase in silt and clay. It is assumed that, at any one site, the sand content was essentially uniform throughout the profile when the drift was deposited. The variations of silt and clay are plotted to this sand standard, because it is regarded as the most immobile material.

The Allenwood soils on pre-Wisconsinan drifts (fig. 2 and table 4, samples 1–5) have a thick B horizon with greater clay content than the Leck Kill (sample 6) and Lackawanna (sample 7) soils on Wisconsinan drifts. These appears to be, however, no textural basis for age differentiation between the pre-Wisconsinan soils. The IIB_t horizon in profile 4 is in a residual soil. The Leck Kill soil (sample 6) on early Wisconsinan till shows only a slight increase of clay in the B horizon. The Lackawanna channery loam (sample 7) on late Wisconsinan Olean till shows no increase in clay content in the B_t horizon and lacks a B_t horizon (Ciolkosz, 1978).

Table 3.—Color of B horizons in pre-Wisconsinan drift soils

Drift	Hue	Value	Chroma
White Deer till	7.5YR	5	6
Laurelton drift	5.0YR	6	6–8
Penny Hill drift	5–2.5YR	6	7–8

AGES OF THE DRIFTS

The relative ages of the three pre-Wisconsinan drifts are based on geographic distribution, stratigraphic succession in soil pit exposures, and soil profile development on the basis of rubefaction (degree of redness) and slightly different amounts of pedogenic clay in the B horizon.

The White Deer till appears to be superposed on the Laurelton drift and its associated paleosol in several pits in the White Deer valley north of the map area. West of Selinsgrove, a basement exposure showed Laurelton till overlying probable Penny Hill till. At the Beavertown quarry west of Middleburg, deeply weathered, probable Penny Hill till underlies colluvium containing a post Laurelton type of soil. These exposures of buried, deeply weathered tills seem to indicate long weathering intervals between deposition of successive tills. The ages shown in the correlation chart are assigned accordingly.

The Muncy drift, which is described by geologists of the Pennsylvania Geological Survey and is the equivalent of these three drifts, is recognized in the Allenwood quadrangle west of the West Branch Susquehanna River and in the Muncy and Washingtonville quadrangles east of the river (Jon D. Inners and John H. Way, personal commun., 1984). Neither the Laurelton nor the White Deer drifts have been identified east of the Susquehanna River. Recent work in 1985 by Crowl also failed to distinguish varieties of drift in the Sunbury and Trevorton quadrangles east of the Susquehanna River.

QUATERNARY HISTORY

The glaciation related to the Penny Hill drift of middle Pleistocene (pre-Illinoian?) age is the oldest ice advance recognized in the central Susquehanna valley. The ice advanced south and southwest across the intermontane area between the branches of the Susquehanna River, down the main valley of the Susquehanna River to Little Mountain on the east and to the North Branch Mahantango Creek on the west (fig. 1). Ice filled the main and most trenching valleys and buttressed the mountain ridges along the western border of Snyder County.

Deposition of the Penny Hill drift was followed by an intense weathering episode in which a thick, red soil developed on all stable parts of the landscape. The strong soil colors and abundant clay content of post-Penny Hill soils beneath White Deer till and Laurelton drift contrast with those on younger drifts and suggest that the post-Penny Hill weathering interval was longer or more intense than later interglacial episodes.

Ice associated with the Laurelton drift invaded the Susquehanna lowland, presumably in early Illinoian time, and extended south at least to Selinsgrove and dammed into the tributary valleys. Some of the transverse course of lower Penns Creek may date from Laurelton ice diversion of meltwater. During the post-Laurelton interglacial interval, soil soils again formed across the landscape.

The White Deer till represents the latest pre-Wisconsinan ice advance and is presumably late Illinoian in age. Ice extent and, presumably, thickness were much less than in the Laurelton glacial episode. Sangamonian age soil soils developed in White Deer till.

In early Wisconsinan time, ice advanced down the West Branch Susquehanna River around the end of Bald Eagle Mountain, and almost to the area covered by White Deer till. A hiatus significantly longer than Holocene time existed in this area between early and late Wisconsinan ice advances as indicated by better developed B horizons in Leck Kill soil on early Wisconsinan drift than on late Wisconsinan drift. No end moraines of early Wisconsinan age were recognized in the central Susquehanna valley, and therefore, the ice sheet may have receded without major stillstands or readvances in the area south of the late Wisconsinan border.

Late Wisconsinan ice advanced to a rather irregular border extending diagonally across the state from the Salamanca reentrant in western N.Y. to Berwick on the Susquehanna River, thence eastward to Belvidere, N.J., on the Delaware River. This reference is marked by valley-train gravel in this part of Pennsylvania. Peripheral processes produced a widespread mantle of colluvium throughout the entire region (Peltier, 1949; Clark, 1968). This colluvium includes shale chip (grezes lessivés) deposits and block fields like those on Bald Eagle Mountain along U.S. Route 322 south of Williamsport and at Hickory Run boulder field (Smith, 1963; Sevon, 1975; Sevon and others, 1975). Presumably, colluvium was formed during earlier glacial episodes, but much of the record was formed and preserved on slopes in Wisconsinan time. This colluvium either has buried older colluvium or has been intermixed. Silt and sand were blown from exposed outwash surfaces and deposited close to the Susquehanna River in basin and flank sand. Paleowind direction appears to have been predominantly from the west and northwest.

Holocene time has been characterized by relative land stability and by incipient soil development. Erosion has been confined largely to steep slopes and along stream courses. Eolian and colluvial processes were relatively insignificant during the Holocene in contrast to late Wisconsinan time. By inference, conditions of relative slope stability, soil formation, and localized erosion probably reached during previous interglacial times in the central Susquehanna valley, but such stable conditions alternated with glacial intervals of ice advance, meltwater erosion and deposition, and extensive colluvial activity.

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